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Air Quality and Biofuels

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1. Introduction

The energy sector has played a crucial role in the context of the global economy as well as the socio-economic development. The world energy consumption is growing at the rate of 2.3% per year. The Energy Information Administration estimated that the primary sources of energy consisted of petroleum 36.0%, coal 27.4% and natural gas 23.0% amounting to 86.4% share for fossil fuels in primary energy consumption in the world (EIA, 2010). Fossil fuel consumption is the largest contributor to air pollution, greenhouse gas emissions and the environmental impacts with a large endowment of coal and has an energy system that is highly carbon intensive. The combustion of fossil fuel releases VOCs, nitrogen oxides (NOx), carbon monoxide (CO) and particulate matter (PM). The combination of VOCs and NOx with sunlight further results in the formation of tropospheric ozone, the main component of smog. The burning of fossil fuels produces around 21.3 billion tonnes (21.3 giga tonnes) of carbon dioxide (CO_2) per year and the natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tonnes of atmospheric carbon dioxide (USDoE, 2007). Coal combustion also leads to sulphur dioxide (SO_2) emissions with serious implications for local pollution (Shukla, 1997). Biomass burning is also recognized as a significant global source of emissions contributing as much as 40% of gross carbon dioxide and 38% of tropospheric ozone (Levine, 1991). Besides, 1.4 million tonnes of methane (CH_4) emissions are also reported from burning traditional biomass fuels. Apart from these emissions, there are a number of other environmental problems associated with energy use. Thus, the energy system is turning out to be ‘unsustainable’ in the 21st century.

In recent years, researchers have recognized the importance of holistic thinking. Current Kyoto-based approaches to reduce the earth’s greenhouse gas involve seeking ways to reduce emissions. Biofuels have emerged as one of the most strategically important alternative fuel sources and are considered as an important way of progress for limiting greenhouse gas emissions, improving air quality and finding new energetic resources (Delfort et al., 2008). A fuel is considered as biofuel if it is derived from biomass such as agricultural products or residues, industrial and urban residues, wood residuals and forest products, either as liquid or as gas (Granda et al., 2007; Prasad et al., 2007a). It encompasses mainly bioethanol, biodiesel, biogas and biohydrogen (NREL, 2006). Ideally a biofuel should be carbon neutral and should therefore not contribute to the overall accumulation of carbon in the atmosphere (Oliveira et al., 2005). Carbon in crops is the result of the photosynthetic conversion of carbon dioxide in the atmosphere (capturing CO_2) into dry matter determined by solar radiation during the growing season (Tilman et al., 2006) and by natural resources (e.g. climate, water) and external inputs (e.g. fertilizers, pesticides). Biofuel is thus considered an important component of the global strategy to reduce green house gas emission, improve air quality and to increase energy security by providing an alternative to fossil fuels (Farrell et al., 2006; Larson, 2006; Prasad et al., 2007b).

The worldwide investment in new biofuels production capacity has also been growing rapidly and was expected to exceed $4 billion in 2007. The value of biofuels production plants under construction and announced construction plans through 2009 exceeded $4 billion in the United States, $4 billion in Brazil and $2 billion in France (REN21, 2008). Biofuels production technologies, despite their techno economic potential have found meagre deployment due to myriad barriers. Recent developments in global climate change negotiations which culminated in the Kyoto Protocol are likely to remove some of the vital barriers to RETs which permitted fossil fuels to externalize the environmental costs. If biofuels want to be part of the solution they must accept a degree of scrutiny unprecedented in the development of a new industry. That is because sustainability deals explicitly with the role of biofuels in ensuring the well-being of our planet, our economy, and our society both today and in the future (Sheehan, 2009).

There are three key arguments for the commercial use of biofuels:

a. Economic-driven rise in consumption, resulting in higher prices for fossil fuels;
b. Energy security and geo-political dependence of regions with a high volatility;
c. Anthropogenic-based CO_2 emissions and climate change.

2. Global biofuel scenario

Soaring prices of fossil-fuels and environmental pollution associated with their use has resulted in increased worldwide interest in the production and use of biofuels. Both developed and developing countries have made mix of policies which have triggered public and private investments in biofuel crop research and development and biofuels production (EPA, 2009; REN21, 2008). Biofuels already constitute the major source of energy for over half of the world's population, accounting for more than 90% of the energy consumption in poor developing countries (FAO, 2005). Presently, biofuels production is expanding, especially in Brazil, the USA and South-East Asia, where sugar cane, maize and palm oil are converted into ethanol or biodiesel (Anonymous, 2008). Over the next several decades, the most certain increase in demand for biofuels is going to focus on displacing liquid fuels for transport, mostly in the form of ethanol which currently supplies over 95% of the biofuels for transportation (Fulton et al., 2004). The world's top ethanol fuel producers in 2009 were the United States with 10.75 billion US liquid gallons (bg) and Brazil (6.58 bg), accounting for 89% of world production of 19.53 billion US gallons (73.9 billion liters or 58.3 million metric tonnes according to data assembled by F.O. Licht. The Global Renewable Fuels Alliance (GRFA) is an international federation representing more than 65 per cent of the world's renewable fuels production from 30 countries. The GRFA predicts global production will reach 85.9 billion litres in 2010 growing by 16.2 per cent from 2009 production (Enagri, 2010). Global production of biodiesel has grown rapidly as well, although starting from a much smaller base. Biodiesel output expanded from 0.23 billion gallons in 2000 to 3.9 billion gallons in 2008 (EPA, 2009). The European Union produces nearly 80 percent of the world's biodiesel, largely from rapeseed; Germany is the single largest biodiesel producer, followed by the United States which produces the fuel mainly from soybeans (Nicholas, 2007). According to Pitkanen et al. (2003) lignocellulosic materials could support the sustainable production of liquid transportation fuels. The 73.9 Tg dry wasted crop material worldwide could potentially produce 49.1 GL year^{-1} of bioethanol (Kim & Dale, 2004), about 16 times higher than the current world ethanol production. The potential bioethanol production could replace 353 GL of gasoline i.e. 32% of the global gasoline consumption (Prasad et al., 2007a).

2.1 Biofuel policies in different countries

Policy choices are instrumental in determining the direction of national as well as global biofuels development. Around the world, governments are considering a number of biofuel policy options. The biofuel policy aims to promote the use in transport of fuels made from biomass as well as other renewable fuels. The central policy of biofuel concerns job creation, greater efficiency in the general business environment and protection of the environment. A range of policies are currently being implemented to promote renewable bioenergy in United States, including the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, the 2002 Farm Bill and the Biomass Research and Development Act of 2000 (FAO, 2008).

Policy targets for renewable energy exist in at least 66 countries worldwide, including all 27 European Union countries, 29 U.S. states (and D.C.) and 9 Canadian provinces. Most targets aim for the 2010–2012 timeframe, although an increasing number of targets aim for 2020. There is now an EU-wide target of 20 percent and a Chinese target of 15 percent of primary energy by 2020. Besides China, several other developing countries adopted or upgraded targets during 2006/2007 (REN21, 2008). China finalized targets for the equivalent of 13 billion liters of ethanol and 2.3 billion liters of biodiesel per year by 2020. The directive sets a European target of 2% substitution of conventional transport fuels by biofuels by December 2005 and a further 5.75% substitution by December 2010. Moreover, the European Commission is committed to encourage the production and use of biofuels by proposing to set a binding minimum target for renewable energy sources of 10% of final energy use in the transport sector by 2020 and is also working on changing fuel specifications to allow higher than 5% blends of biofuel (Lechon, 2009; FAO, 2008).

New U.S. renewable fuels standard requires fuel distributors to increase the annual volume of biofuels blended to 36 billion gallons (136 billion liters) by 2022. The new standard implies that 20 percent of gasoline for road transport would be biofuels by 2022. Several states within the U.S. have also taken steps to promote development and increased use of biofuels. Under the Energy Policy Act of 2005, U.S. renewable transportation fuels are scheduled to reach 7.5 billion gallons by 2012. The 2007 Energy Independence and Security Act require 36 billion gallons of ethanol by 2020, with 21 billion gallons coming from advanced biofuels such as cellulose-based ethanol (Hoekman, 2009). The United Kingdom has a similar renewable fuels obligation, targeting 5 percent by 2010. Japan's new strategy for long-term ethanol production targets 6 billion liters per year by 2030, representing 5 percent of transport energy (FAO, 2008).

Developing countries like India also started Biofuel mission in 2003 to cope with the global fuel crisis. Government of India through a notification in September 2002 made 5% ethanol blending mandatory in petrol in 9 states and 3 Union Territories. In the next phase, supply of ethanol-blended petrol would be extended to the whole country and efforts would be made to increase the percentage of ethanol mixture in petrol to 10 percent (Prasad et al., 2007b). National Biofuel Policy drafted by the Ministry of New and Renewable Energy Sources (MNRE), assures that biofuel programme would not compete with food security and the fertile farm lands would not be diverted for plantation of biofuel crops. The policy deals with a number of issues like minimum support prices (MSPs) for biofuel crops, subsidies for growers of biofuel crops, marketing of oil-bearing seeds, subsidies and fiscal concessions for the biofuel industry, R&D, mandatory blending of auto-fuel with biofuel, quality norms, testing and certification of biofuels. An indicative target of 20% by 2017 for the blending of biofuels–bioethanol and biodiesel has been proposed in the National Biofuel Policy (Indian Express, 2008).

3. Biomass resource base and biofuel generation technology

Since the mid-1970s many research initiatives have focused on increasing the biomass resource base for production of biofuel. Several technologies used for the conversion of plant material into biofuels are available and depend on the type of feedstock; the conventional and new technologies can be classified into the following four groups:

3.1 First generation biofuel technology

In general, first generation biofuels are produced from cereal crops (e.g. wheat, maize), oil crops (e.g. rape, palm oil) and sugar crops (e.g. sugar beet, sugar cane) using established technology. Based on the conversion of sugars (sugar cane) and starch (potato, cassava, maize) or oil (oil palm, rapeseed) accumulated in food crops into ethanol and biodiesel respectively accounts the first generation biofuels (Cassman & Liska, 2007). Some have called for an integrated systems biology approach to define ideotypes that meet the requirements of feedstocks for biofuels. However, the scientific evidence that crop traits can be genetically modified to meet the requirements for fuel without any trade-off on the value as a food crop is absent. Alternatively, different varieties may be developed for food and fuel production.

3.2 Second generation biofuel technology

In general, second generation biofuels are produced from cellulosic materials (Somerville, 2006) and also based on the use of dedicated energy crops like switch grass *(Panicum virgatum)* grown with low external inputs and using conversion methods that result in high net energy efficiency (output/input). Conversion of cellulosic biomass, which is both abundant and renewable, is considered as a promising alternative for ethanol produced from starch or sugar. Plant triacylglycerols are another potential feedstock to produce biofuels, especially biodiesel. Most vegetable oils are derived from triacylglycerols stored in seeds. Novel energy crops may be developed that produce triacylglycerols in non-seed tissues (Durrett et al., 2008). To avoid competition with food crops there is a growing interest in woody/tree borne oil plants. Native energy oil plants are more frequently present in tropical and subtropical regions. Non-edible oils obtained from plant species such as *Jatropha curcas* (Ratanjyot), *Pongamia pinnata* (Karanj), *Calophyllum inophyllum* (Nagchampa), *Hevea brasiliensis* (Rubber) and other oil-based crops can be efficiently used for biodiesel production. *Jatropha curcas* is a drought resistant, perennial oil plant (ca. 40% oil content) with favourable traits to produce biodiesel in unfavourable regions of India, Sub-Sahelian Africa and Latin America (Kumar & Sharma, 2008).

3.3 Third generation biofuel technology

This is based on algae or cyanobacteria that contain a high oil mass fraction (up to 70%) and are grown in ponds. Microalgae are sunlight-driven cell factories that convert carbon dioxide to potential biofuels (Akkerman et al, 2002; Ghirardi et al., 2000). Oil content in microalgae can exceed 80% by weight of dry biomass (Metting, 1996). Depending on species, microalgae produce many different kinds of lipids, hydrocarbons and other complex oils (Guschina & Hardwood, 2006; Metzger & Largeau, 2005). Certain algae and cyanobacteria have high lipid contents (Spolaore et al., 2006) biodiesel derived from microalgal oil (Dunahay et al., 1996; Sheehan et al., 1998). Under proper conditions, these micro-organisms can produce lipids for biodiesel with yields per unit area that are 50-100% higher than those with any plant system (Chisti, 2008). Microalgae can also provide several different types of renewable biofuels which include methane produced by anaerobic digestion of the algal biomass (Gavrilescu & Chisti, 2005) and photobiologically produced biohydrogen (Fedorov et al., 2005; Kapdan & Kargi, 2006).
The microalgae appear to be the only source of renewable biodiesel that is capable of meeting the global demand for transport fuels which will not compromise production of food, fodder and other products derived from crops (Chisti, 2008; Hu et al., 2008). However, it is still not proven that this high efficiency can be maintained after scaling-up the technology to a large production plant. Furthermore, the feedstock is waste derived from plant material used for food and feed. Yet, we do not know what the trade-off is between maximizing the utilization of primary production for food and feed and the use of residues and waste to produce methane or hydrogen. Chemical composition of the residues and waste also will matter.

3.4 Fourth generation biofuel technology

It is based on biohydrogen production by embedding parts of the photosynthesis apparatus in artificial membranes (Kruse et al., 2005). These biofuels are derived from the bioconversion of living organisms (microorganisms and plants) using biotechnological tools. The mean conversion efficiency for the total solar spectrum amounts to ca. 20%, which is on average about 10 times higher than for annual crops. This high efficiency should be considered a potential level. The gap between the potential level and actual efficiency is still not known. Currently, this technology is still expensive and not yet ready for commercial exploitation.

4. Biofuels for improvement in air quality

The emissions from engines using gasoline have SO_2, CO_2, VOCs, nitrogen oxides (NOx), carbon monoxide (CO) and particulate matter (PM), which causes pollution (Gaffney & Marley, 2009). The VOCs emitted from gasoline-fueled vehicles arise from uncombusted or partially combusted fuel and typically include cyclohexane, octanes, and aromatics. The NOx and VOC emissions react in the presence of sunlight by way of a series of photochemical reactions involving hydroxyl, peroxy and alkoxy radicals, to form the secondary pollutant ozone (Finlayson-Pitts & Pitts, 2000). The emissions of NOx and total VOCs lead to the formation of ozone in the troposphere, the main component of smog. CO is a deadly poison and the inhalation of fine particulate matter (PM2.5) is a serious health concern (Peter et al., 2003).
The energy and environmental crisis which the world is experiencing forced to find alternative uses for renewable resources and using clean technologies. Feedstocks include

agricultural and food processing wastes, trees, and various grasses that are converted to ultra-clean (minimal SOx and NOx pollutants) biofuel in elaborate biochemical or thermo-chemical steps. And depending on the choice of a microorganism the bio-conversion can yield cellulosic ethanol, biogas or biohydrogen. Biofuels has a number of health and environmental benefits including improvement in air quality by reducing pollutant gas emissions relative to fossil fuels (Vasudevan et al., 2005). Therefore, it is imperative to develop and promote alternative energy sources that can lead to sustainability of the energy system. Hall & House (1993) have examined the role of biomass in mitigating global warming and contributing to the development of future energy strategies and concluded that the use of biomass for fossil fuel substitution would be far more effective in reducing atmospheric CO than to simply sequester CO_2 in forests in most circumstances. Currently, the second generation biofuels are projected to reduce carbon emissions by 90%, and by 2040 these could potentially replace up to 40% of all conventional fuels (Krisztina et al., 2010).

4.1 Combustion profile of biofuels

The success of oxygenated gasoline has sparked interest in the use of oxygenated compounds as emissions reducing additives in diesel fuel. Oxygenated compounds used as diesel additives are structurally similar to diesel fuel but have one or more oxygen atoms bonded to the hydrocarbon chain. Numerous oxygenated compounds have been investigated as either diesel fuel additives or replacements and have shown emissions reducing properties.

4.1.1 Properties and combustion profile of ethanol

Although ethanol was always a good oxygenate candidate for gasoline, the compound first approved by Environmental Protection Agency was methyl tertiary butyl ether (MTBE), a petrochemical industry product (Gaffney & Marley, 2000). The introduction of MTBE in gasoline has been studied as a classic case of solving one problem (reducing vehicle carbon monoxide emissions) while causing a new problem (persistent contamination of water systems with MTBE). Use of MTBE increased until 1999, but reports then appeared of environmental pollution incidents caused by MTBE spillage; US bans on MTBE came into force during 2002. Presently, ethanol is prospective material for use in automobiles as an alternative to petroleum based fuels. The main reason for advocating ethanol is that it can be manufactured from natural products or waste materials, compared with gasoline, which is produced from non-renewable natural resources. Ethanol can be independently used as a transportation fuel together with additives (e.g. ignition improver, denaturing agents, etc.). In addition, instead of pure ethanol, a blend of ethanol and gasoline is a more attractive fuel with good anti-knock characteristics (Al-Hasan, 2003).
Ethanol contains 34.7% oxygen by weight, and adding oxygen to fuel results in more complete fuel combustion, and therefore contributes to a reduction in exhaust emission and petroleum use (Huang et al., 2008; Prasad et al., 2007b). Ethanol is a high octane fuel and its use displaces toxic octane boosters such as benzene, a carcinogen. Ethanol is a virtually sulfur free additive and is biodegradable. Thus, it's easy to see why many states use ethanol to reduce vehicular emissions. The physical and thermo-physical properties of ethanol compared to the other fuels (gasoline and diesel) indicates that ethanol is more suitable and environmentally safe fuel (Table 1) as its normal boiling point lies in between gasoline and diesel, while heating value, carbon and sulfur content are lower (Lynd, et al., 1991; Vaivads et al., 1995).

Properties	Ethanol	Gasoline	Diesel
Density (g cm^{-3})	0.785	0.737	0.856
Normal boiling point (ºC)	78.00	38-204	125-400
Lower heating value, LHV (kJ cm^{-3})	21.09	32.05	35.66
LHV (kJ g^{-1})	26.87	43.47	41.66
Energy (MJ l^{-1})	23.10	32.84	33.32
Energy (MJ kg^{-1})	29.40	47.46	46.94
Carbon content (%)	52.20	85.50	87.00
Sulfur content (ppm)	0.00	~200	~250

Table 1. Comparison of thermo-physical properties of ethanol, gasoline and diesel fuel

A comparison of flammability variables for neat diesel, ethanol and gasoline clearly showed that ethanol (Table 2) falls between diesel and gasoline in terms of flashpoint and flammability temperature limits (Battelle, 1998). In the engine durability tests conducted by Meiring and coworkers (1983), no abnormal deterioration of the engine or fuel injection system was detected after 1000 hrs of operation on a blend containing 30% dry ethanol, small amount of octyl nitrate ignition improver and ethyl acetate phase separation inhibitor and the remainder diesel fuel. The Chicago Transit Authority in the US monitored the condition and overall performance of a fleet of 30 buses, of which 15 were the control run on number one diesel. After completion of 434,500 km distance by the 15 buses running on the blend, no abnormal maintenance or fuel related problems were encountered (Marek & Evanoff, 2001).

Characteristics	Neat diesel	Neat ethanol	Neat gasoline
Vapour-pressure at 37.8 °C (kPa)	0.3	17	65
Flash point (°C)	64	13	-40
Auto-ignition temperature (°C)	230	366	300
Flammability limits (%)	0.6-5.6	3.3-19.0	1.4-7.6
Flammability limits (°C)	64-150	13-42	-40-18

Table 2. Approximate fuel ethanol characteristics related to flammability

Low-percentage ethanol-gasoline blends (5-10%) can be used in conventional spark-ignition engines with almost no technical change. New flex-fuel vehicles of which there are over 6 million running mainly in Brazil, United States and Sweden, can run on up to 85% ethanol blends that had modest changes made during production. Ethanol combustion offers fuel and emissions savings due to the high octane number, the high compression ratio and the combustion benefits from ethanol vapour cooling which partly offsets its lower energy content per liter (IEA-ETE, 2007).

4.1.2 Properties and combustion profile of biodiesel

Biodiesel is a mono-alkyl ester based oxygenated fuel made from vegetable oil or animal fats. It has properties similar to petroleum based diesel fuel and can be blended into conventional diesel fuel. This interest is based on a number of properties of biodiesel, non toxic and its potential to reduce exhaust emissions (Jha, 2009; Knothe et al., 2006). The advantages of biodiesel as diesel fuel are its portability, ready availability, renewability, higher combustion efficiency, lower sulfur and aromatic content (Knothe et al., 2006; Ma &

Hanna, 1999), higher cetane number, and higher biodegradability (Mudge & Pereira, 1999; Speidel et al., 2000; Zhang et al., 2003). Biodiesel is by nature is an oxygenated fuel with oxygen content of about 10%. This improves combustion and reduces CO, soot and unburnt hydrocarbon.

Biodiesel is non-flammable and, in contrast to petrodiesel, is non explosive. The flash point of biodiesel (>130 °C) is significantly higher than that of petroleum diesel (64 °C) or gasoline (−45 °C) (Anonymous, 2010a). Biodiesel has a density of ~0.88 g/cm³, higher than petrodiesel (~0.85 g/cm³). Biodiesel has better lubricating properties and much higher cetane ratings than today's lower sulfur diesel fuels (Knothe et al., 2005; Mittelbach & Remschmidt, 2004). Biodiesel addition reduces fuel system wear (Anonymous, 2010b) and in low levels in high pressure systems increases the life of the fuel injection equipment that relies on the fuel for its lubrication. The calorific value of biodiesel is about 37.27 MJ/L (Elsayed et al., 2003). Variations in biodiesel energy density are more dependent on the feedstock used than the production process and properties of biodiesel from different oils are shown in Table 3 (Chhang et al., 1996; Rao & Gopalakrishnan, 1991). Biodiesel has virtually no sulfur content, and it is often used as an additive to Ultra low sulphur diesel (ULSD) fuel to aid with lubrication, as the sulfur compounds in petrodiesel provide much of the lubricity.

Biodiesel from Vegetable oil	Kinematic Viscosity mm^2/s	Cetane no:	Heating value MJ/kg	Flash Point °C	Density kg/l
Peanut	4.9	54	33.6	176	0.883
Soybean	4.5	45	33.5	178	0.885
Babassu	3.6	63	31.8	127	0.875
Palm	5.7	62	33.5	164	0.880
Sunflower	4.6	49	33.5	183	0.860
Diesel	3.06	50	43.8	76	0.855
B20 (20%blend)	3.2	51	43.2	128	0.859

Table 3. Approximate fuel biodiesel characteristics related to flammability

Since the key properties of the biodiesel are comparable to those of diesel fuel, it can be used in all diesel engines with little modification or no modification either on its own or as a blend with conventional or low sulphur diesel (Ryan, 1999). The disadvantages of biodiesel are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions, lower engine speed and power, injector coking, engine compatibility, high price and greater engine wear. The technical disadvantages of biodiesel fossil diesel blends include problems with fuel freezing in cold weather, reduced energy density and degradation of fuel under storage for prolonged periods. However there are solutions to this such as using a blend of biodiesel upto B20 which has a gelling point of –15 degrees F, adding a biodiesel additive such as Fuel Boost to the blend also lowers the gel point even further and useful in the winter (Petracek, 2011).

4.1.3 Properties and combustion profile of biogas

Biogas is a renewable fuel produced by anaerobic fermentation of organic material (Pathak et al., 2009). The value of a substrate in the biogas process depends on its potential as a high yield plant species and on the quality of the biogas produced such as the achievable methane content. The most suitable plant species for the production of biogas are those which are rich in degradable carbohydrates such as sugars, lipids and proteins, and poor in hemicelluloses and lignin, which have a low biodegradability (El Bassam, 1998). Its composition varies with the source, but usually it has 50–70% CH_4, 25–50% CO_2, 1–5% H_2, 0.3–3% N_2 and traces of H_2S (Bedoya, 2009). Methane is the only combustible constituent of biogas, which is utilized in different forms of energy. Biogas can be used for heating, lighting, transportation, small-scale power generation, and large gas turbines as a complementary fuel (e.g., to natural gas) (Bedoya, 2009). Constraints like cost of cleaning, upgrading (to remove CO_2) and transportation of biomass limit the use of biogas (Jahangirian et al., 2009).

Methane is very light fuel gas. If we increase the number of hydrogen and carbon atoms, we have got progressively heavier gases, releasing more heat, therefore more energy, when ignited. Specific gravity of methane is 55 which is less than petrol & LPG. This means that biogas will rise if escaping, thus dissipating from the site of a leak. This important characteristic makes biogas safer than other fuels. It does not contain any toxic component; therefore there is no health hazard in handling of fuel. The calorific value of biogas is 5000-7000 Kcal/m^3. In calorific value, one cubic meter of biogas is equivalent to 0.7 m^3 of natural gas, 0.7 kg of fuel oil and 4 kWh of electricity (Asankulova & Obozov, 2007).

Motive power can be generated by using biogas in dual fuel internal combustion (IC) engine. Air mixed with biogas is aspirated into the engine and the mixture is then compressed, raising its temperature to about 350°C, which is the self-ignition temperature of diesel. Biogas has a high (600°C) ignition temperature. Therefore, in order to initiate combustion of the charge, a small quantity of diesel is injected into the cylinder just before the end of compression. The charge is thus ignited and the process is continued smoothly. Converting a spark-ignition engine for biogas fueling requires replacement of the gasoline carburettor with a mixing valve (pressure-controlled venturi type or with throttle). A spark-ignition engine (gasoline engine) draws a mixture of fuel (gasoline or gas) and the required amount of combustion air. The charge is ignited by a spark plug at a comparably low compression ratio of between 8:1 and 12:1. Power control is affected by varying the mixture intake via a throttle (Biogas Digest, 2010). Biogas has very high octane number approximately 130. By comparison, gasoline is 90 to 94 & alcohol 105 at best. This means that a higher compression ratio engine can be used with biogas than petrol. Hence, cylinder head of the engine is faced so that clearance volume will be reduced and compression ratio can sufficiently increase. Thus volumetric efficiency and power output are increased.

4.2 Biofuels for GHGs emission reduction and air quality

Vehicular emissions from petroleum products in the form of CO, NOx, unburnt hydrocarbons and particulates are of high environmental concern especially in air pollution (Subramanian et al., 2005). Thermal power plants are a major source of SPM (suspended particulate matter) and solid waste. The inefficient burning of biomass causes exposure to various pollutants and is considered a major health hazard and has been shown to lead to lung and chest problems among women and children (Smith, 1987). Biofuels has a number of health and environmental benefits including improvement in air quality by reducing pollutant gas emissions relative to fossil fuels (Vasudevan et al., 2005). Therefore, it is imperative to develop and promote alternative energy sources that can lead to sustainability of the energy system. This would not only warrant major reforms in the energy policies and infrastructure, but also huge international investments.

4.2.1 Reduction in exhaust emission by ethanol

Ethanol is one of the best tools available today to reduce air pollution from vehicles. Ethanol-diesel emulsion gives beneficial results in terms of pollution emission reduction in engines (Jha, 2009; Knothe et al., 2006). It is found that a remarkable improvement in PM-NOx trade-off can be achieved by promoting the premixing based on the ethanol blend fuel having low evaporation temperature, large latent heat and low cetane number as well, in addition, based on a marked elongation of ignition delay due to the low cetane number fuel and the low oxygen intake charge (Ishida et al., 2010). As a result, very low levels of NOx and PM which satisfies the 2009 emission standards imposed on heavy duty diesel engines in Japan, were achieved without deterioration of brake thermal efficiency in the PCI engine fuelled with the 50% ethanol blend diesel fuel and the high exhaust gas recirculation (EGR) ratio. It is noticed that smoke can be reduced even by increasing the EGR ratio under the highly premixed condition (Ishida et al., 2010). A 41% reduction in particulate matter and 5% NOx and 27% CO emission has been observed with 15% ethanol blends. Emission tests conducted especially on ethanol-diesel blends (Table 4) confirm the effect of substantially reducing particulate matter (Prasad et al., 2007b).

Pollutant	Emission (%)		Emission (g/km)	
	10% ethanol	15 % ethanol	22% ethanol	100 % ethanol
Particulate matter	27	41	0.08	0.02
NOx	4	5	0.45	0.34
Carbon monoxide	20	27	0.76	0.65
Unburned hydrocarbons	-	-	0.004	0.02
Sulfur dioxide	-	-	0.064	0.0

Table 4. Reduction in pollution emission with different percentages of Ethanol blending

If blended at the refinery, as opposed to "splash blending" outside the refinery, ethanol-blended gasoline can reduce NOx emissions as well, thus further reducing the potential for smog. Compared with conventional unleaded gasoline, ethanol is a particulate-free burning fuel source that combusts with oxygen to form carbon dioxide, water and aldehydes. Gasoline produces 2.44 CO_2 equivalent kg/l and ethanol 1.94 (Popa, 2010). Since ethanol contains 2/3 of the energy per volume as gasoline, ethanol produces 19% more CO_2 than gasoline for the same energy. When compared to gasoline, depending on the production method, ethanol releases less green house gases and savings of GHG emissions from ethanol produced from various crops are seen (Wang et al., 2009). Ethanol could play an important role in reducing petroleum consumption by enabling a substantial increase in the fuel efficiency of gasoline engine vehicles. This ethanol boosted engine concept uses a small amount ethanol to increase the efficiency of use of a much larger amount of gasoline by approximately 30%. Gasoline consumption and the corresponding CO_2 emissions would thereby be reduced by approximately 25%. In combination with the additional reduction that results from the substitution of ethanol for gasoline as a fuel, the overall reduction in gasoline consumption and CO_2 emissions is greater than 30% (Cohn et al., 2005).

4.2.2 Atmospheric pollution reduction by biodiesel

Biodiesel is a clean-burning renewable fuel that is compatible with petroleum diesel and can be produced domestically. The biodiesel performs as well as diesel while reducing the emissions of particulate matter, carbon monoxide (CO), hydrocarbons, oxides of sulphur (SOx), particulate matter and smoke density (Ali et al., 1995; Bagley et al., 1998; Durbin et al., 2000; Koo & Leung, 2000). Biodiesel is considered as 'carbon neutral' because all the carbon dioxide (CO2) released during consumption had been sequestered from the atmosphere for the growth of vegetable oil crops (Barnwal and Sharma, 2005). Other environmental benefits of biodiesel include the fact that it is highly biodegradable and appear to reduce emissions of air toxics and carcinogens (relative to diesel). The benefits of 100% (B 100) and 20% (B 20) biodiesel blending, in terms of per cent pollutants emission reduction (Planning Commission of India, 2003) and reduction emission in g/km for 10 and 15 % blend (Vasudevan et al., 2005) is shown in Table 5. According to the EPA's Renewable Fuel Standards Program Regulatory Impact Analysis, released in February 2010, biodiesel from soy oil results an average of 57% reduction in greenhouse gases compared to fossil diesel, and biodiesel produced from waste grease results in an 86% reduction (Petracek, 2011).

Pollutant	Emissions reduction (%)		Emission (g/km)		
	B 100	B20	Diesel	B 10	B 15
Particulate matter	-30	-22	0.129	0.093	0.080
NOx	+13	+2	0.79	0.83	0.89
Carbon monoxide	-50	-20	0.77	0.65	0.62
Unburned hydrocarbons	-93	-30	0.37	0.22	0.16
Sulfur dioxide	-100	-20	--	---	---

*(-) and (+): Less and more % of pollutant emission from biodiesel in comparison to 100% diesel

Table 5. Reduction in pollution emission with different percentages of biodiesel blending

Biodiesel has higher cetane number, lower sulfur content and lower aromatics than that of conventional diesel fuel. It also reduces emissions due to presence of oxygen in the fuel (Subramanian et al., 2005). In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel. Of the major exhaust pollutants, both unburned hydrocarbons and nitrogen oxides are ozone or smog forming precursors. The use of biodiesel results in a substantial reduction of unburned hydrocarbons. However, a marginal increase in NOx (1-6%) is reported (Table 5) for biodiesel use in many engines. Emissions of nitrogen oxides are either slightly reduced or slightly increased depending on the duty cycle of the engine and testing methods used. Based on engine testing, using the most stringent emissions testing protocols required by EPA for certification of fuels or fuel additives in the U.S., the overall ozone (smog) forming potential of the hydrocarbon exhaust emissions from biodiesel is nearly 50 percent less than that measured for diesel fuel (Petracek, 2011). The summary report given by NREL stated that the maximum estimated increase and decrease in daily maximum 1-hour or 8-hour ozone concentrations due to the use of either a 100% or 50% penetration of a B20 fuel in the HDDV fleet in any of the areas studied is +0.26 ppb and –1.20 ppb for 1-hour ozone and the 100% B20 fuel scenario. As the maximum ozone increase (+0.26 ppb) is well below 1 ppb, the use of biodiesel is estimated to have no measurable adverse impact on 1-hour or 8-hour ozone attainment in Southern California and the Eastern United States (Morris et al., 2003). The mass concentration of the particles/smoke decreased up to 33% when the engine burned 100% biodiesel as fuel, compared to the 100% petroleum diesel (Zou and Atkinson, 2003).

4.2.3 Atmospheric pollution reduction by biogas

The fossil fuels combustion leads to emission of air pollutants such as CO, NOx, SO_2, volatile organic compounds and particulates (Parashar et al., 2005). Biogas technology, besides supplying energy and manure, provides an excellent opportunity for reducing environmental hazards and pollution through substituting firewood for cooking, kerosene for lighting and cooking and chemical fertilizers (Pathak et al., 2009). The benefits of biogas are generally similar to those of natural gas. In addition, burning biogas reduces greenhouse gas (GHG) emissions; it reduces the net CO_2 release and prevents CH_4 release. Thus, biogas combustion is a potential means to satisfy various legislative and ecological constraints (Jahangirian et al., 2009). Borjesson & Berglund (2006) analyzed fuel-cycle emissions of CO2, CO, NOx, SO_2, hydrocarbons (HC), CH_4, and particles from a life-cycle perspective for biogas systems based on different digestion technologies and raw materials. They suggest that the overall environmental impact of biogas depends largely on the status of uncontrolled losses of CH_4, the end-use technology that is used, the raw material digested, and the energy efficiency in the biogas production chain.

Biogas is a smokeless fuel offering an excellent substitute for kerosene oil, cattle dung cake, agricultural residues and firewood which are used as fuel in most of the developing countries (MNES, 2006). Burning of kerosene, firewood and cattle dung cake as fuels emits 0.8 to 2.2, 0.7 to 4.0 g kg^{-1} NOx, and SO_2, respectively along with varying amounts of CO, volatile organic compounds, particulate matters, organic matter, black carbon and organic carbon (Table 6).

A family size biogas plant substitutes 316 L of kerosene, 5,535 kg firewood and 4,400 kg cattle dung cake per annum as fuels. Substitution of kerosene reduces emissions of NOx, SO_2 and CO by 0.7, 1.3, and 0.6 kg $year^{-1}$. Substitutions of firewood and cattle dung cake results in the reduction of 3.5 to 12.2, 3.9 to 6.2, 436.9 to 549.6 and 30.8 to 38.7 kg $year^{-1}$ NOx, SO_2, CO and volatile organic compounds, respectively. Total reductions of NOx, SO_2, CO and volatile organic compounds by a family size biogas plant are 16.4, 11.3, 987.0 and 69.7 kg $year^{-1}$ (Pathak et al., 2009).

Pollutants	Pollution reduction due to a biogas plant (kg $year^{-1}$)			
	Kerosene	Firewood	Dung cake	Total
Oxides of N (NOx)	0.7	12.2	3.5	16.4
Oxides of S (SO_x)	1.3	3.9	6.2	11.3
Carbon monoxide	0.6	549.6	436.9	987.1
Volatile organic compounds	0.2	38.7	30.8	69.7
Particulate matter^{10}	0.1	16.6	13.2	29.9
Particulate matter$^{<2.5}$	0.1	11.6	28.6	40.3
Organic matter	0.4	7.2	17.6	25.2
Black carbon	0.1	3.3	11.0	14.4
Organic carbon	0.1	19.4	55.4	74.9

Table 6. Pollution reductions due to use of biogas plant

The biogas used as vehicle fuel presents better characteristics than the natural gas (Table 7). Some disturbance still appears for the NOx emissions, but they stay below the EU norms.

Concerning CO_2, hydrocarbons and CO emissions, the biogas is far better than the Natural Gas used for Vehicles (NGV), (Traffic & Public Transport Authority, 2000).

Pollutant	Emission (g/km)		
	Diesel	Natural Gas	Biogas
Particulate matter	0.1	0.022	0.015
NOx	9.73	1.1	5.44
Carbon monoxide (CO)	0.2	0.4	0.08
Unburned Hydrocarbons (HC)	0.4	0.6	0.35
CO2	1053	524	223

Table 7. Pollution reductions due to biogas used as vehicle fuel

Methane has a greenhouse gas (GHG) heating factor 21 times higher than CO_2. Combustion of biogas converts methane into CO_2 and thereby reduces the GHG impact by over 20 times. Combustion of biogas reduces the flame temperature, which reduces NOx emissions since the main pathway for NOx formation is thermal (Lafay et al., 2007). The digester reduces emissions of methane, carbon dioxide and ammonia from manure while in the enclosed vessel. Combustion of the biogas releases some carbon dioxide and sulphur compounds back into the atmosphere. However this combustion process releases carbon dioxide, which was captured by plants in the last year by the crop fed to the animals in contrast to fossil fuels, which are releasing carbon from ancient biomass.

4.3 Effect of biofuels on health

The exhaust gases from transportation vehicles contain many types of gaseous and particulate air pollutants, including trace levels of some particulate polycyclic aromatic hydrocarbons (PAHs) which have adverse effects on human health (Prasad et al., 2007b; Subramanian et al., 2005). Burning of biomass or any solid fuel, most closely associated with air quality problems and has some negative impacts on health (Pathak et al., 2009), particularly when burned in household cooking/heating stoves where there is little or no ventilation. Exposure to particulates from biomass burning causes respiratory infections in children, and carbon monoxide is implicated with problems in pregnancy. Coal and biomass are also suspected of causing cancer, where exposure rates are high (Smith, 1993). Petroleum fuels produce aromatic compounds of a polycyclic nature which are responsible for producing cancer in humans. But increased levels of NOx and HC may effects the human health as these may contain carcinogenic HC as well. If these productions can be reduced then considerable reduction in cancer amongst human beings can be hoped for. So for all of these reasons and biofuel production should be increased to improve our environmental as well as physical health (Wang et al., 1997).

It is highly likely that the net public health impact of using biofuels is beneficial. This is likely true even if the alleged negative impacts of ethanol and biodiesel blending (NOx, permeation) are assumed to be true. This theory is supported by the fact that: (1) ethanol and biodiesel blending significantly reduces emissions of pollutants that are generally believed to pose the greatest public health threat (PM and Toxics i.e. Hazardous Air Pollutants or HAPs); and (2) the actual ozone impact of the alleged increases in NOx and permeation emissions, if assumed to be true, is negligible or extremely small (Coleman, 2011). Ozone levels are significantly increased, thereby increasing photochemical smog and aggravating medical problems such as asthma (Hulsey, 2006; Jacobson, 2007).

4.3.1 Bioethanol and human health

On the positive side, the use of alcohols and alcohol/petroleum blends in diesel engines has been shown to reduce emissions of the potentially carcinogenic carbonaceous soot particles (Gaffney et al., 1980; Wang et al., 1997). Dynamometer studies of the use of gasahol (10% ethanol in gasoline) in motor vehicles report an average decrease in total HC emissions of 5%, a decrease in CO emissions of 13% with an increase in NOx emissions of 5% (HEI, 1996). The same studies showed a decrease in the emissions of the air toxics, benzene and 1, 3-butadiene of 12% and 6%, while acetaldehyde emissions increased by 159%. Although the atmospheric reactivity of ethanol is much lower than that of gasoline, no significant change was reported in the overall atmospheric reactivity (Maximum Individual Risk, MIR) of the exhaust emissions from gasohol when the higher reactivity of acetaldehyde is included. In terms of the health-related PAH emissions, some marked reductions were demonstrated for less toxic gaseous PAHs such as naphthalene, but the particulate PAH emissions, which have more implications for adverse health effects, remaining virtually unchanged and did not show a statistically significant reduction (Zou & Atkinson, 2003).

4.3.2 Biodiesel and human health

The use of biodiesel in a conventional diesel engine results in a substantial reduction of unburned HC, CO and particulate matter compared to emissions from diesel fuel (Table 5). Biodiesel exhaust emission has been extensively characterized under field and laboratory conditions. Biodiesel reduces emissions of CO and CO_2 on a net lifecycle basis and contain fewer aromatic hydrocarbons. Biodiesel can also reduce the tailpipe emission of particulate matters. Vellguth (1983) proved that rapeseed oil methyl esters (RME) are an adequate substitute for fossil diesel fuel (DF). Bünger and his coworkers (1998) investigated the mutagenic and cytotoxic effects of diesel engine exhaust (DEE) from a modern passenger car using rapeseed oil methyl esters (RME) biodiesel as fuel and directly compared to DEE of DF derived from petroleum. The results indicated a higher mutagenic potency of DEE of DF compared to RME due to the lower content of polycyclic aromatic compounds (PAC) in RME exhaust. The existing engines can use 20% biodiesel blend without any modification and reduction in torque output (Vasudevan et al., 2005). The use of a B20 fuel in the HDDV fleet is estimated to reduce the per million risk of premature death due to exposure to air toxics in the SoCAB region of southern California by approximately 2% and 5% respectively (Table 8) for the 50% and 100% HDDV fleet penetration of B20 biodiesel in the HDDV fleet emission scenarios calculated with no indoor/outdoor (I/O) effects and accounting for I/O effects on an annual average and hourly basis, (Morris et al., 2003).

Scenario	Std Diesel Risk	50% B20 Fuel		100% B20 Fuel	
		Risk	(%)	Risk	(%)
No I/O Effects	1950	1910	-2.1	1835	-5.9
Annual I/O Effects	1284	1261	-1.8	1216	-5.3
Hourly I/O Effects	1257	1235	-1.8	1191	-5.3

Table 8. Average risk (out of a million) of premature death for the standard diesel base case and the 50% and 100% penetration of B20 biodiesel in the HDDV fleet emission scenarios

Scientific research confirms that biodiesel exhaust has a less harmful impact on human health than petroleum diesel fuel. Pure biodiesel emissions have decreased levels of polycyclic aromatic hydrocarbons (PAH) and nitrited PAH compounds that have been identified as potential cancer causing compounds. Also, particulate matter, an emission linked to asthma and other diseases, is reduced by about 47 percent, and carbon monoxide, a poisonous gas, is reduced by about 48 percent (Sinobioenergy, 2011). Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments as biodiesel produces less sulfur emissions than regular diesel. The public health benefits of reduced particulate and HAP exposure from biofuels outweigh the negligible smog impact of any relative small NOx and permeation emissions increases from biofuels blends (Coleman, 2011).

4.3.3 Biogas and health benefits

Biogas can have significant health benefits especially in rural areas. According to the Integrated Environmental Impact Analysis carried out by Biogas Support Program for 600 biogas users and 600 non-users, four percent more non-biogas users have respiratory diseases (Tables 9) than those who own biogas plants (BSP, 2000).

Disease	Problems in the past (HHs)*		Present status of HHs	
	Yes	No	Improved	Remained same
Eye Infection	72	18	69	3
Cases of burning	29	71	28	1
Lung problem	38	62	33	5
Respiratory problems	42	58	34	8
Asthma	11	89	9	2
Dizziness/headache	27	93	16	11
Intestinal/diarrhea	58	42	14	44

Table 9. Health benefits of biogas

Qualitative information from various household surveys carried out by BSP has revealed that problems like respiratory illness, eye infection, asthma and lung problems have decreased after installing a biogas plant. According to the Biogas Users' Survey conducted in 2000 with 100 households (HHs*), biogas can have positive impacts on the health of its users. Out of 42 respondents who had respiratory problems in the past, it was reported that the problem has improved for 34 of them. Similarly, those who had problems like asthma, eye infections and lung problems found that their problems had decreased after displacing dirtier fuels with biogas. If parasitic diseases had previously been common, the improvement in hygiene also has economic benefits (reduced working time). The more fully the sludge is digested, the more pathogens are killed. High temperatures and long retention times are more hygienic. The following are the principal organisms killed in biogas plants: Typhoid, Paratyphoid, Cholera and dysentery bacteria (in one or two weeks), Hookworm and bilharzia (in three weeks), Tapeworm and roundworm die completely when the fermented slurry is dried in the sun. Biogas has a positive effect more on rural health conditions.

5. Fuel economy in biofuel blends engines

Ethanol (E100) consumption in an engine is approximately 51% higher than for gasoline since the energy per unit volume of ethanol is 34% lower than for gasoline (Chauhan et al., 2011). The higher compression ratios in an ethanol-only engine allow for increased power output and better fuel economy could be obtained with lower compression ratios than gasoline-powered engines. In flexible fuel vehicles, the lower compression ratio requires tunings that give the same output when using either gasoline or hydrated ethanol. A 2004 MIT study (Stauffe, 2006), and an earlier paper published by the Society of Automotive Engineers, identified a method to exploit the characteristics of fuel ethanol substantially better than mixing it with gasoline (Stokes et al., 2000). The improvement consists of using dual-fuel direct-injection of pure alcohol (or the azeotrope or E85) and gasoline, in any ratio up to 100% of either, in a turbocharged, high compression-ratio, small-displacement engine having performance similar to an engine having twice the displacement. Direct cylinder injection raises the already high octane rating of ethanol up to an effective 130 and resulted in over-all reduction of gasoline use and CO_2 emission of 30%.

Biodiesel blends can reduce emission levels of HC (hydrocarbons) and CO (carbon monoxide); however, biodiesel blends may somewhat increase emission levels of NOx (oxides of nitrogen) in some engines. Biodiesel blends, used in new, low emissions engines may not significantly affect emissions. B20 is most widely used by fleets in the United States, because B20 balances performance, EPA emission levels, costs, and availability. B20 is also the minimum blend level that qualifies as an alternative fuel, in compliance with the Energy Policy act of 1992. Blends lower than B20 are used regionally, depending on favorable tax incentives that vary from state to state. However, NOx and evaporative VOCs (permeation) are regulated to control ozone formation, and recent air shed model runs suggest that the use of ethanol (E10) and biodiesel (up to B20) do not measurably increase actual ozone levels. With regard to permeation emissions, it is useful to remember that permeation (an evaporative VOC) is a very small percentage of any state's overall gasoline hydrocarbon emissions inventory (e.g. ~ 4% in California), and that ethanol generally reduces tailpipe (i.e. non-evaporative) hydrocarbon emissions as (at least a partial) offset. Also, because ambient temperature is a primary catalyst for fuel permeation, states with colder climates than California will have much lower permeation rates (Coleman, 2011).

6. Further scope of biofuels on environmental benefits

Tackling air pollutions and climate change requires the simultaneous deployment of available commercial clean technologies, demonstration and commercialisation of technologies at the advanced research, development and demonstration stage and research into new technologies. So for centuries, biofuels has been playing a vital role in the provision of energy services at the household level. However, at the beginning of the 21st century large scale commercial use of biofuel is the most rapidly growing renewable energy source in the developed countries as well as developing countries. Several clean energy options are viable today and several others are likely to be so in the future, as technologies improve, costs are reduced, and the competitive landscape for biofuel technologies evolves.

The Intergovernmental Panel on Climate Change has considered a range of options for mitigating climate change and increased use of biomass for energy features in all of its scenarios. The biomass takes an increasing share of total energy over the next century, rising to 25±46% in 2100 in its five scenarios. In the biomass intensive energy scenario, with biomass providing for 46% of total energy in 2100, the target of stabilizing CO_2 in the atmosphere at present-day levels is approached. Annual CO_2 emissions fall from 6.2 Gt C in 1990 to 5.9 Gt C in 2025 and to 1.8 Gt C in 2100: this results in cumulative emissions of 448 Gt C between 1990 and 2100, compared to 1300 Gt C in their business-as-usual case (IPCC, 1996).

However, developing countries with tropical climates may have a comparative advantage in growing energy rich biomass and second generation technologies could enable expansion of the range of feedstock used from the traditional sugarcane, maize, and rapeseed to grasses and trees that can thrive in less fertile and more drought prone regions. Biodiesel production efforts are focused on using non-edible oil seeds from plants (*Jatropha curcas*, *Pongamia pinnata* and other tree borne oilseeds) and animal fats like fish oil. The focus is to encourage the use of wastelands and other unproductive land for the cultivation of these relatively hardy new biofuel crops so that biofuel feedstock crop cultivation does not compete with food crops for scarce agricultural land and water (Singh, 2009).

As ethanol yields improve or different feedstocks are introduced, ethanol production may become more economically feasible. Currently, research on improving ethanol yields from each unit of feedstock is underway using biotechnology. Also, as long as oil prices remain high, the economical use of other feedstocks such as cellulose, become viable. Environmental costs per unit of ethanol decline with higher biomass yield, lower fertilizer and fuel inputs into biomass production, and improvements in biomass to biofuel conversion efficiencies (Cassman and Liska, 2007). By-products such as straw or wood chips can be converted to ethanol. Fast growing species like switch grass can be grown on land not suitable for other cash crops and yield high levels of ethanol per unit area. The development of commercial cellulosic technology would allow agricultural residues to be used and increase ethanol yield per hectare.

The biogas plants may reduce the dependence on conventional sources of energy by the turn of the century, provided promotional efforts are continued. Although, cattle dung has been recognized as the chief raw material for bio-gas plants, other materials like night-soil, poultry litter and agricultural wastes are also used where they are socially acceptable.

Climate change, air quality and energy security will change the way energy is used and supplied over the next century. Supplying increasing amounts of clean and secure energy will be a challenge that will require a great deal of innovation and investment. There are plenty of biomass resource and technology options for biofuel productions that could lead to emissions reductions in the heat, transport and electricity sector, while improving energy security and air quality.

7. Conclusion

Biofuels are non-polluting, locally available, accessible and reliable fuels obtained from renewable sources. Biomass can act as a reservoir of carbon or as a direct substitute for fossil fuels with no net contribution to atmospheric CO_2 if produced and used sustainably. Fuel security and the reduction of air pollution are some of the fundamental gains of an expanded biofuels industry. When particularly favorable improvements in technology over the next decade are assumed, the costs of emissions from biofuel could be approximately equal to, but unlikely less than, those of conventional gasoline. Cellulosic ethanol holds the promise of yet greater environmental benefits, but economical ways of producing it must first be discovered. New biofuel feedstocks especially low input cultivation of non-food crops (e.g., *Jatropha*, hybrid poplar, new varieties of switchgrass, and better multispecies plant mixtures) and algal biodiesel production technology may also yield substantial improvements. Biofuel markets can serve as an opportunity to trigger additional investments that could lead to increased production of food as well as biofuel crops by small-scale farmers. Further research on the use of indigenous non-food crops should be encouraged. Conversely, other ways of increasing biofuel production may increase air pollutant emissions unless accompanied by simultaneous improvements in abatement technology. Consideration should also be given to improved emissions controls and increases in fuel efficiency and fuel conservation that would reduce the need for increased fuel imports. Thus biofuels provide lots of environmental benefits including reduction of greenhouse gas emissions, improvement in air quality, reduction of fossil fuel use, increased national energy security, increased rural development and a sustainable fuel supply for the future and it also requires careful assessment on its impact of the environment especially in lowering greenhouse emissions.

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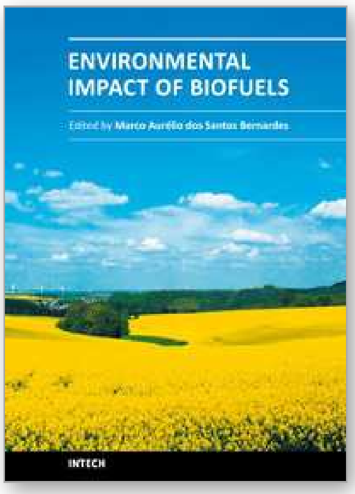

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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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